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INVESTIGATION OF DOUBLE-STREAM ELECTRON-WAVE SYSTEMS

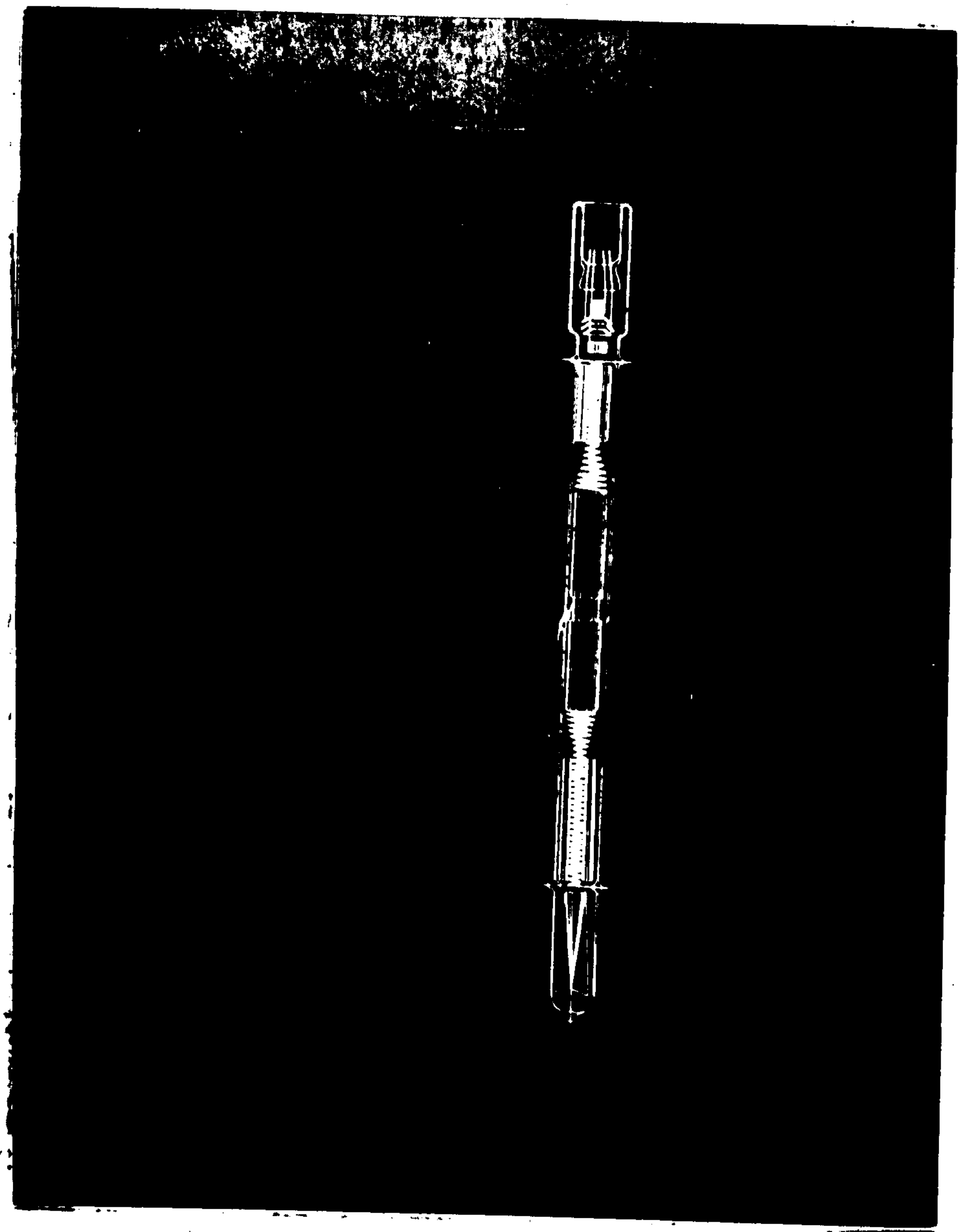
Summary

The results of an experimental investigation of double-stream amplifiers in the metre (100-200 megacycles) and 10 cm range are presented. The comparison of principal experimental results and the results of theoretical analysis are given.

1. Introduction

The first two papers devoted to the experimental investigations of double-stream amplifiers were published in USA in 1949 /1, 2/. Even in these early works some positive and negative properties of the double-stream systems were brought to light; among positive properties the following may be mentioned: the significant gain, the broad bandwidth, and the theoretical possibility of mm-wave range amplification. At the same time the cathode system becomes more complicated as compared with T.W.T and it is necessary to use modulating and demodulating devices of helix type which causes the same obstacles in the range of mm waves as in T.W.T.

However, since the number of published works dealing with experimental investigations of double-stream systems is very small, we can not think that double-stream amplifiers got their definitive place among the modern microwave electron devices. Therefore, the result of experimental investigation of double-stream amplification in the metre (100-200 mega-



cy[illegible]) and [illegible] cm range, carried out in the USSR IRE, Academy of Sciences, are of some interest.

II. Optimal operating conditions of amplification

The simplest small signal theory for one-dimensional electron stream plasma double stream system /1/ in which the electron stream frequencies are equal ($\omega_1 = \omega_2 = \omega_p$), shows that the system characteristics are determined by the factor $X = \frac{\delta \omega}{u \omega_p}$ where: ω - the angular frequency of u.h.f. oscillations.

$$\delta = \frac{1}{2}(u_1 - u_2)$$

$$u = \frac{1}{2}(u_1 + u_2)$$

u_1 and u_2 - electron velocities of the first and second streams. At $X = 0.85$, the system is in the optimal operating conditions and gives maximum amplification which is equal to:

$$4.35 \frac{\omega_p}{u} \quad \text{db/cm}$$

In fig. 1 an ordinary system of a double-stream amplifier is illustrated. The typical data of two models for 100-300 megacycles and 3000 megacycles are:

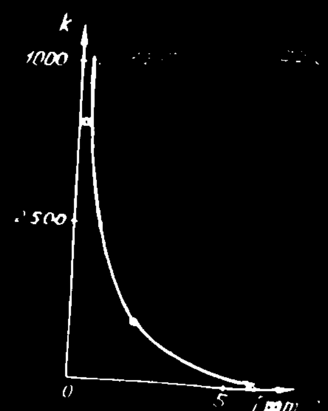
both streams current - 5 ma and 30 ma;

average velocity - 100 V, and 1000 V.;

stream diameters - 15 mm and 5 mm.

The gain of similar systems with the drift tube length about 20-25 cm was of the order of 40 50 db.

The analysis of optimal conditions of amplification obtained experimentally has shown that qualitatively the relation between principal parameters of the [illegible] determined



Fig

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by factor X has been well proved. For optimal gain in the most different conditions and at a very great change of frequency (from 100 to 3000 megacycles) the values obtained for the factor X are about 0.3 to 0.5. (When calculating the factor X the decrease $f\omega_p$, caused by the final beam size and presence of the surrounding metallic drift tube /3/ was taken into account).

The experimental gain values lie between the theoretical values obtained from the formula 4.35 $\frac{\omega_p}{u}$ db/cm where decrease in plasma frequency was either taken into account or neglected.

Thus, it may be assumed that at the first approximation, the simple one-dimensional theory is in satisfactory agreement with the experiment and, therefore, may serve as a basis in the design of such devices.

III. <u>Mixing of electron streams</u>

An extremely important parameter in a real double-stream system is the degree of electron stream mixing.

For experimental investigations at frequencies of 100 to 300 megacycles a model with two strip like electronic beams was devised. The distances between the beams were fixed at 0.3, 3 and 6 mm in different experiments. Fig. [illegible] shows the experimental points of gain values of the above model. The theoretical curve is also drawn in fig. 3. As it may be observed from this figure, there is a very good agreement of the experimental and theoretical data.

For the most models of the metre range the electronic

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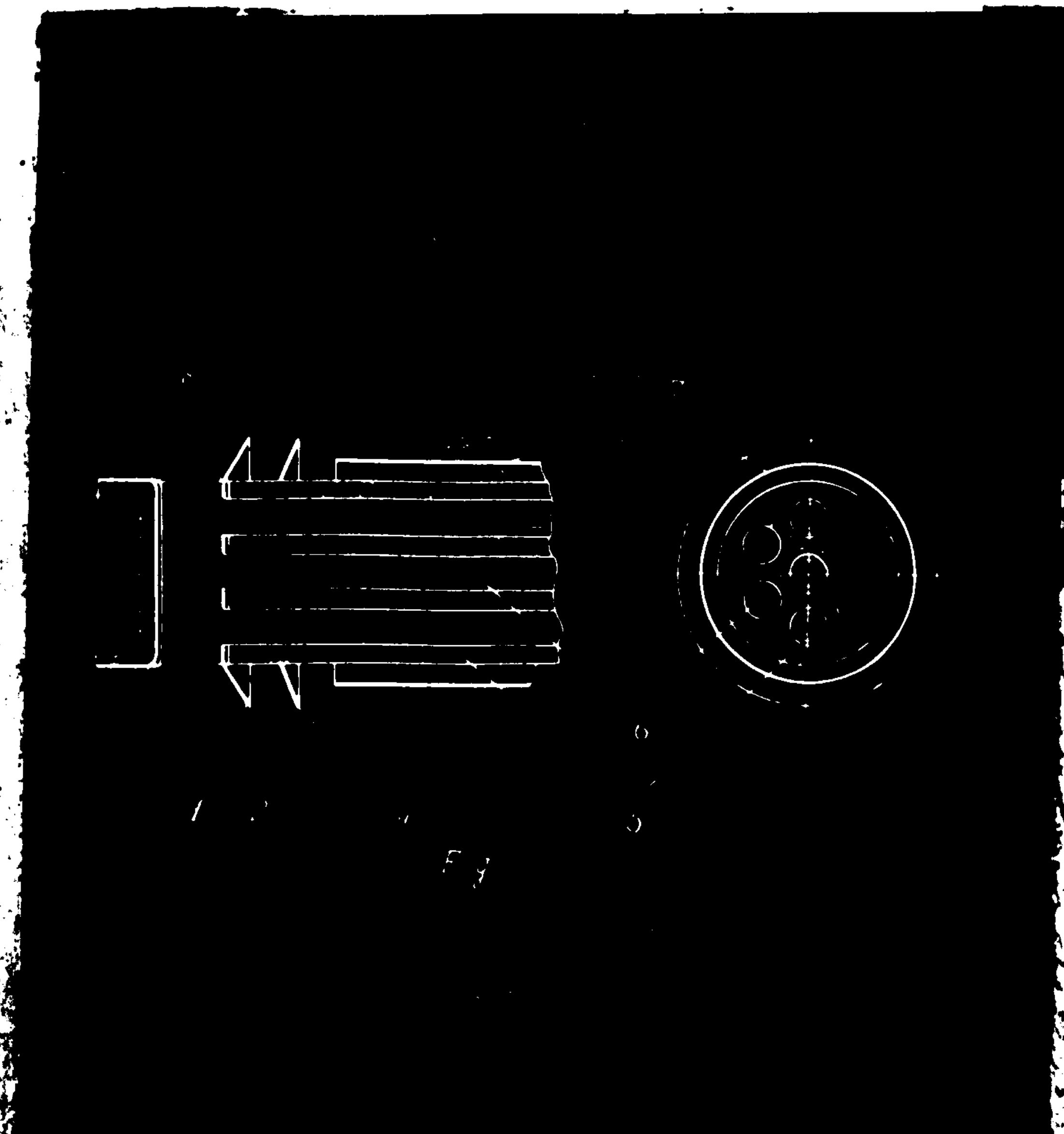

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guns have been used, which produce two coaxial annular beams focused by homogeneous magnetic field.

Much better mixing was obtained in double-stream systems with centrifugal electrostatic focusing by introducing one electron stream into another. As it was previously mentioned /4/, such systems yielded a gain in the metre range up to 60-70 db at a stream current of the order 2 to 4 ma.

Electron mixing in 10 cm range must be much better than in the metre range and therefore, it is very difficult to create a cathode system which would meet these requirements. After a number of attempts an extremely simple electron gun has been developed; this electron gun, being provided with magnetic focusing, produces in 10 cm range an efficient double-velocity electron stream. Fig. 3 gives a schematic illustration of this gun. Part of electrons from the fast-moving stream is used for heating the cathode which produces the slower stream and that is principal feature of this gun. Therefore, this gun is only a little more complicated than those of the ordinary TWT. The guns of this type provided the conditions for stable operation of models.

IV. Noise and output power

In practice the optimal conditions of amplification in the metre range may be obtained when the current in both beams is of the order of 1 to 5 ma and 20 to 60 ma in 10 cm range. (Such changes of the current values are due to the fact that ω_p must increase).

Small operating currents in the metre range and large currents in the centimetre range, present in the first case a possibility of combining the high amplification inherent . double-stream mechanism with the low level of noise, and in the second case - with the large power output.

In the process of experiment, the noise factors of the order of [illegible] db., were obtained in the metre range. It should be mentioned, however, that no attempts have been made to construct special noiseless double-stream guns. With the noise factors of this order, the double-stream mechanism does not introduce any specific additional noise so that the noise factor is determined only by the electron gun noise

In certain conditions of a double-stream gun operation abnormally high noises arise. These are, probably, due to backward electron streams, as the abovementioned operating conditions are characterized by the minimum potential in the gun caused either by the potential drop in one of the electrodes, or by the influence of the space charge.

A special model with a movable system of electrodes which allowed to change distance between the first and the second cathode has been used to investigate the influence of this distance on the system noise. With the noise factors of the order of 1[illegible] to 1[illegible] db., it was impossible to trace any relation between the noise and the distance between the cathodes.

In devices of 10 cm range with the guns shown on fig. [illegible] the noise factor of 40 to 50 db. was obtained due to the increase of operating current. These noise factor values are similar to those of the mean power T. W. T.

The increase of the beam current up to about 4 ma makes it possible to obtain output energies of the order of 5 watts at a frequency of 3000 megacycles.

It is obvious, that the top radio frequency output of a double-stream system will increase with the increase of current and average velocity of the stream, as well as with the increase of velocity difference which supplies the energy for amplification of radio-frequency wave. The experimental data given in table 1 show that this dependence is considerable.

In order to obtain higher energy from the double-velocity electron stream, sufficiently effective output systems must be employed. It was proved by experimental investigations that the mechanism of interaction between the beams and delayed wave in a helix pierced by the modulated double-velocity stream, is similar to that in a single-stream TWT. When the velocities of streams differ greatly, the two gain optimums corresponding to the velocities of these streams may be observed. These maximums merge when the velocity difference is small. The double velocity stream bound by double-stream interaction and the single-velocity stream with summary current when passing through the helix, produce similar values of small signal gain and of maximum output.

Thus, it may be noted that in order to design an output helix of the double-stream amplifier, the theory of an ordinary TWT may be used.

V. <u>On the decrease of operating wave-length.</u>

Mean current of about 0.5 ma per cm^2 is sufficient to provide double stream amplification in the frequency band from 100 to 200 megacycles. At a frequency of 3000 megacycles, the densities required are of the order of 10 ma per cm^2. It may be expected that with the current densities of about 1 ampere per cm^2, a double-stream gain will take place at a frequency of 30000 megacycles approximately. The main difficulty will, probably, be the construction of the cathode and focusing systems capable to provide double-velocity electron stream with this current density and high degree of different velocity electron mixing, because the mixing at frequencies of the order of 30000 megacycles must be perfect.

References

1. A. Haeff PIRE, v. 37, N 1, p. 4, 194[illegible].

2. A. V. Hollenberg, BSTJ, v. 2[illegible], N 1, p. 33, 194[illegible].

3. G. M. Branch, T. G. Michran IRE Transaction, v. ED-[illegible], N [illegible], p. 3, 1955.

4. [illegible] Chernov "Radiotechnics and electronics", v. [illegible], N 1[illegible], p. 14[illegible], 19[illegible].

Fig. 1 Schematic diagram of double-stream amplifier

Fig. [illegible] Theoretical curve and experimental points of double-stream amplification VS the distance between strip beams.

Fig. 3. Schematic diagram of a double-stream electron-gun for models of 10 cm range:

1 - cathode for fast stream; [illegible] - cathode for slow stream (the heating of this cathode is accomplished by means of electronic bombardment with the part of electrons emitted by first cathode); 3 - first cathode heater; 4 - anode; 5 - slow-stream; [illegible] - fast stream; [illegible] - drift tube; 8 - oxide layer.

ТАБЛИЦА 1.

$$V_2 + \Delta V = V_1$$

ΔV V	V_2 V	I ma	G db	P_{max} W	ω_p Mc	$\frac{\delta\omega}{\omega_p}$ %
115	430	18	28	0,01	720	0,26
220	700	18	38	0,04	590	0,36
300	800	19	82	0,16	570	0,48
400	1000	80	37	0,5	640	0,46
450	1100	82	44	2,5	630	0,41
450	1100	36	46	4,5	660	0,39